Bed Formation in Compound Straight Channel

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Abstract. From the past years, flooding often happen in Malaysia, especially at the end of year. This disaster greatly affects our daily lives such as water damage to houses, disruption of transportation, reduction of income and damage of furniture and other appliances. Even these disasters can cause death in humans and animals. Frequent flood incidents and soils erosion problem may lead to sedimentation in the drainage and river system due to urbanisation. Therefore, effort to understanding on these phenomena becomes more important to estimate conveyance capacity of rivers in Malaysia for flood risk management. It is important to understand the flow behaviour and sedimentation problem in the river system during flood. In order to understand, the laboratory study on the flow characteristics in a compound straight channel flow is undertaken. The effects of flow on uniform sandy bed channel and its formation are studied by using a modified flume with an asymmetric compound straight channel. The finding on the experimental works such as stage-discharge relationship, Manning's n, depth-averaged velocity distribution and bed formation were presented in this paper. In this study, it was found that the bed morphology, erosion and deposition of sediment process are significantly influenced by the water velocity in the channel. The pattern of bed form for staggered and tandem array vegetation is quite similar in terms of erosion and sedimentation. Based on results, the maximum level of erosion for tandem array is 40mm meanwhile for staggered vegetated is 60mm. The bed forms show that the erosion occurs at upstream and slightly occurs at downstream part. In this study, the bed form profiles are repeating ripples and dunes.

Introduction

From the past years flooding often happen in Malaysia especially at the end of each year. This disaster greatly affects our daily lives such as water damage to houses, disruption of transportation, reduction of income and damage of furniture and other appliances [1]. Even these disasters can cause death in humans and animals. Throughout Malaysia, the areas worst affected with this natural disaster were Kelantan, Terengganu and Johor. However, the areas affected by flooding are recently increasing.

A flood can be determined as any high water that dominated the natural or artificial banks in any part of the river system [1]. Flooding occurs in overflow state where the water exceeds the capacity of a channel [2]. A part of the river discharge is carried by the main channel and the rest is carried by floodplain. In overflow state, at the main channel the velocity of the flow reduced while at the floodplain water depth was increase. Meanwhile, during flooding if a river flows over its banks, the shear layer will develops between the fast flowing main channel and the flow in floodplain is slower [3]. In addition, during flooding the main channel may not fully convey the total discharge and compound channel configuration can happen [4]. The presence of vegetated on floodplain such as trees and grass is significantly influence the flow behaviour of the river become more complex. Vegetation on the floodplain is might grow naturally or planted for the purpose of river bank erosion prevention. However, the existences of vegetation can causes problems such as slow flow and increase the water depth which leads to risk.

The aim of this study is to determine the effects of flow on uniform sandy bed channel and its formation with an asymmetric compound straight channel. The objectives of the research study are to carry out the stage-discharge relationship, Manning's n coefficient, depth-averaged velocity distribution and bed formation in vegetated compound straight channel. The experimental laboratory that has been carried out in the Hydraulic and Hydrology Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Johor Baharu. This study is focussed on the flow characteristics on vegetated compound straight channel with mobile bed. The floodplain vegetation is placed in two-line staggered and tandem arrangements. The finding of experimental works is covered the study of flow characteristics for non-vegetated and vegetated cases at different relative depth (DR) which is DR=0.30 and DR=0.50.

Previous Studies

The study on the flow characteristics in mobile bed with non-vegetated and vegetated has been discussed by various researches previously. The existing methods and equations has been described before are also discussed in this study. The research focused on stage-discharged relationship, manning's n, depth-averaged velocity distribution and bed formation.

Stage-Discharge Relationship

The stage-discharge curve shows the relationship between depth of flow and flow discharge. Discharge is obtained from the point velocity data. Meanwhile, the flow discharge of the channel is determined by using the midsection method. The present of vegetation on the floodplain affect the depth of flow due to discharge capacity. In that case, the flow of water on floodplain become slower than in main channel and water level arises and inundated floodplain. The extra roughness's of the floodplain influence the lower discharge capacity and retards the overall discharge.

There are some factors that affect the discharge capacity in compound channel with vegetation on the floodplain which is (i) relative depth of floodplain to the main channel, (ii) the roughness of the floodplain and the main channel, (iii) the number of floodplain, (iv) the ratio of the floodplain width to main width, (v) the value of side slope on the main channel and (iv) the aspect ratio of the main channel [5].

Manning's n

Manning is dimensionless, its value depend on the nature of the channel and its surface. The flow of water in an open channel causes friction between the flowing water and the channel boundary layer. The friction is a result of the degree for roughness on the wall and the bed of the channel which is represented by Manning's n [5]. The Manning's n always changing and depends on a number of factors. Hence, a basic knowledge of factor should be known to choose the appropriate value for Manning's n [6]. There a several factors that affecting the Manning's n value in the channel. The following are the basic factors that need to consider such as surface roughness, vegetation and stage-discharge [7].

For the surface roughness, the size and shape of material is representing surface roughness where that forms the wetted perimeter and created a retarded effect on the flow. On the other hand, stage and discharge also influence the Manning's n. The decreases of Manning's n will increase in stage and discharge. However, the Manning's n value can be larger at high stage if the bank is grassy and rough. Besides that, vegetation are also can be categorised as one of surface roughness. The present of vegetation at the floodplain also reduce the capacity of the channel and retarded the flow. This is due to the height, density, distribution and the type of vegetation [7].

The presence of vegetated has higher Manning's n compared to non-vegetated. This is because the changes in roughness surface between main channel and floodplain [6].However, values of Manning's n may varies depend on the density and arrangement of the emergent vegetation such as tandem and staggered arrangements. Jumain *et al.*claims that the staggered arrangement has higher flow resistance compared to tandem arrangement because of arrangement ofvegetation [2]. The additional resistance on staggered arrangement tend to increase the value of Manning's n.

Velocity Distribution

The distribution of velocity in the channel cross-section is not uniform because of the presence of free surface and friction along the channel and bed. The velocity vector of the flow also affected with the presence of corner boundaries and bends in the channel. The direction of flow not only changes in the longitudinal direction but in lateral as well as the normal direction of flow [8]. There are many factors influences the velocity distribution in open channel section such as the shape of the section and channel roughness [3].

Ibrahim claimed that, the velocity in the main channel is higher than floodplain because of momentum transfer when water overflow from main channel into floodplain [9]. The momentum transfer process disturbed with the presence of vegetation. Besides that, the velocity also reduces when the flow moves from the main channel to the floodplain. The velocity is reduced because of the momentum transfer from the main channel to the floodplain. Besides, according to Yonesi *et al.*, the result shows at the main channel, that maximum velocity did not occurs at the flow surface while at the floodplain, the maximum velocity still occurs at the main channel [10]. Ibrahim stated that in vegetated cases, the velocity at vegetated areas is lower and near to zero value compared to non-vegetated case where velocity is higher on main channel [9]. These observations confirm that the velocity distribution consequently have an effect on the bed formation.

Sediment Transport

Hickin stated that not all channel will transport sediment and formed in sediment. It was difficult to understand sediment transport in river due to it processes that intermediate between the flowing water and the channel boundary [11]. Erosion consists of the removal and transport of sediment where it is mainly from the boundary. Besides, deposition involves the transport and placement of sediment on the boundary. Erosion and deposition are what form the channel of any alluvial river as well as the floodplain through which it moves [11].

Bed formation

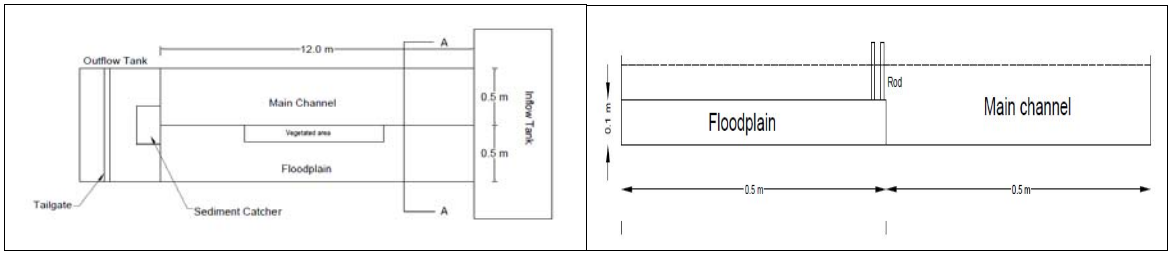
The changes of river interrelated not only with bank erosion but also involve in bed deformation due to relationship between water and sediment transport during the water flow [12]. The changes of bed formation in the main channel are significantly influenced by the water velocity in the channel. The bed formation processes involve sedimentation and erosion phenomena due to water flow in main channel. Sedimentation occurs when the level of sand surface is higher than the datum level whereas erosion occurs is the level of sand surface is lower than the datum level. There are factors that affected the bed formation in the main channel which is water depth, bed slope, density sediment and size of bed material [13].

Research Methodology

This study involved data collection through experimental works by using a straight compound channel. Several equations also are used to obtain the accurate results.

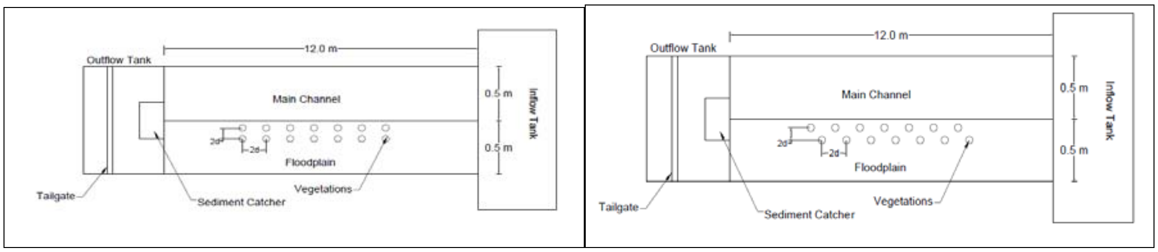
The Experimental Set-Up and Equipment

In this research, the experiment were performed in a rectangular compound straight channel with 12.0m long, 1.5m wide which consists of 0.5 meter wide. The depth of the main channel is 0.1 meter with 1/1000 channel bed slope. The type of material used in the experiment is uniform graded sand of size$d_{50} = 80mm$. Figure 1 (a) and (b) shows a plan view and cross-section view of flume. The material that used to constructed floodplain is waterproof plywood. Moreover, steel rod has been used to simulate the present of emergent vegetation. The 5 mm diameter (d) and 15 cm height steel rods was arranged along the floodplain area in two-line tandem and two-line staggered with 2d horizontal and laterally spacing as shown in Figure 2 and respectively.



(a) (b)

Figure 1 (a) and (b): A plan view and cross-section view of flume



(a) (b)

Figure 2 (a) and (b): Tandem and staggered arrangement of vegetation in straight compound channel

This laboratory work involves in different equipment are used to measure different types of data. A digital point gauge is used to measures water surface elevations and bed profile on physical models. A digital point gauge was able to measure to nearest reading $\pm\ 0.1\ mm$. Besides that, a portable flow meter is installed to measure flow discharge in the channel. The experiments were conducted under uniform flow condition in order to apply uniform flow theory in the analysis. The uniform flow is obtained when relative discrepancy between the water surfaces is, S_{ws} and the channel bottom (S) is less than 5%. The results are discussed for the two different relative depth which is DR=0.30 and DR=0.50. There are several equations that have been used in this study such as relative depth and Manning's roughness coefficient.

The flow depth is obtained from digital point gauge by measuring water surface and channel bed level. Relative depth value was obtained from calculation by using equation (1). Meanwhile, the experimental value of Manning's is determined by using the formula as shown in Equation (2). In addition, The Cox method in Equation (3) was used to determine the theoretical Manning's n coefficient. Manning's coefficient is representing the degree of roughness of the wall and the bed channel.

$$\mathrm{DR} = \frac{(H-h)}{H} \tag{1}$$

Where DR is relative depth (mm/mm), H is mean water depth in main channel (mm) and h is height of main channel from bed level (mm).

$$n = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{Q} \tag{2}$$

Where Q is discharge ($\frac{m^3}{s}$), n is Manning's roughness coefficient($sm^{-\frac{1}{3}}$), A is coefficient cross-sectional flow area (m^2), R is hydraulic radius (m), S is channel of slope (m/m).

$$n_c = \frac{\sum_{i=1}^{N}(n_i A_i)}{A} \tag{3}$$

Where n_c is composite Manning's roughness coefficient, A is water cross-sectional area, n is Manning's roughness coefficient and N is number of subsections.

Results and Discussion

The experimental Reynolds number (Re) exceeds 4000 and Froude number (Fr) is less than 1. Therefore, the regime of flow is classified as subcritical-turbulent. The result of the stage-discharge relationship, Manning's n coefficient, depth-averaged velocity distribution and bed formation is presented in this section to understand the flow characteristics in the compound straight channel. All the results are based on the objective of the study. The uniform flow is established in order to apply uniform theory in the analysis.

Stage-discharge relationship

The stage-discharge relationship for compound straight channel with non-vegetated and vegetated experiments is plotted through the H-Q curve. Based on the Figure 3, the result clearly shown that flow depths are steadily increases with an increase in discharge for each case. For non-vegetated case, the maximum flow depth obtained is 0.201m and the lowest flow depth obtained is 0.060m. For staggered vegetated case, the maximum flow depth is 0.215m and the lowest flow depth obtained 0.134m. On the other hand, for tandem vegetated case, the maximum flow depth obtained is 0.208m and the lowest flow depth obtained is 0.131m. These results show that the highest value of flow depth is occurring in staggered vegetation case followed by tandem vegetation case and lastly non-vegetation case. This is because the existences of vegetation on the floodplain significantly increase the bottom roughness and overall resistance. Since, there are differences; it leads to an increase of the velocity gradient between main channels and floodplain flows. Therefore, the water flow is slow down and causes the water level increase in the main channel compared to channel with non-vegetated.

Figure 4 shows the relationship between relative depth (DR) and discharge (Q) in compound straight mobile bed channel. Based on the Figure 4, the relative depth value is increased steadily with discharge. From observation it shows that relative depth of vegetated cases is higher instead of non-vegetated case. In vegetated cases, relative depth of staggered vegetated is higher than tandem vegetated cases due to arrangement of vegetation. The staggered vegetation is more complex and denser arrangement compared tandem arrangement which it can makes flow of water become more difficult to flow through. This finding only conducted in overbank flow because the vegetation is place in edge of floodplain. For the reason, the effect only is generated in overbank flow.

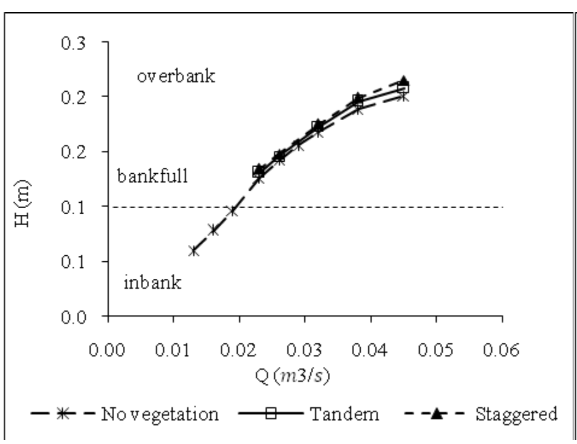


Figure 3: The stage-discharge relationship

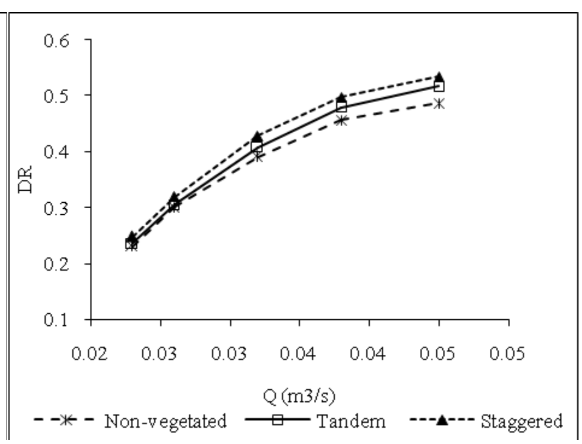


Figure 4: Relationship between relative depth and discharge

Determination of Manning's n

For this study, experimental and theoretical Manning‘s n is determined using the Equation (2) and (3). Table 1 and 2 show the experimental and theoretical Manning's n for relative depth 0.3 and 0.5 respectively. Based on Table 1, there are increases in the value of Manning's n along the channel in downstream direction. For non-vegetated cases the Manning's n value increases from 0.0151 to 0.0167. On the other hand, for tandem vegetation arrangement, the value also increases from 0.0178 to 0.0256. This is because at the main channel, flows of water toward downstream area make the sediment become deposited on the bed since the energy creates by upstream flow. This condition leads to increases the flow resistance and decrease velocity near the mobile bed.

Besides that, there are differences between Manning's n value for non-vegetated and emergent vegetation. Based in Table 1, the experimental Manning's n value for non-vegetated floodplain at 0.375 is 0.0151 while for vegetation floodplain with tandem arrangement is 0.0183. The resistance in the non-vegetated section are only involved by bed wall and bed surface. Meanwhile, the resistance at vegetated section also involved by the bed surface and bed wall but the presence of vegetated along the floodplain also affect the resistance.

On the other hand, Manning's n is quite difference for tandem and staggered arrangement of vegetation. The results in Table 2 shows that at 0.750 for staggered arrangement has higher Manning's coefficient which is 0.0250 compared to tandem arrangement is 0.0246. It confirms that staggered arrangement of vegetation has higher resistance and increase the surface roughness coefficient. This is due to due to effect of vegetation arrangement which create additional resistance to flow hence produce to higher Manning's n [2].

Table 1: Computed experimental and Cox Method Manning's n for (a) Non-vegetated Floodplain (b) Vegetated Floodplain with Tandem Array and (c) Vegetated Floodplain with Staggered Array at DR = 0.30

x/L	Experimental n	Cox Method n_c	% Difference
0.250	-	-	-
0.375	0.0151	0.0150	0.66
0.500	0.0152	0.0151	0.66
0.625	0.0167	0.0165	1.20
0.750	-	-	-

(a)

x/L	Experimental n	Cox Method n_c	% Difference
0.250	0.0178	0.0166	6.74
0.375	0.0183	0.0182	0.55
0.500	0.0193	0.0193	0.00
0.625	0.0224	0.0223	0.45
0.750	0.0256	0.0251	1.95

(b)

x/L	Experimental n	Cox Method n_c	% Difference
0.250	0.0182	0.0178	2.20
0.375	0.0196	0.0194	1.02
0.500	0.0196	0.0190	3.06
0.625	0.0219	0.0211	3.65
0.750	0.0249	0.0238	4.42

(c)

Table 2: Computed experimental and Cox Method Manning's n for (a) Non-vegetated Floodplain (b) Vegetated Floodplain with Tandem Array and (c) Vegetated Floodplain with Staggered Array at DR = 0.50

x/L	Experimental n	Cox Method n_c	% Difference
0.250	-	-	-
0.375	0.0185	0.0188	1.62
0.500	0.0208	0.0214	2.88
0.625	0.0206	0.0208	0.97
0.750	-	-	-

(a)

x/L	Experimental n	Cox Method n_c	% Difference
0.250	0.0190	0.0202	6.32
0.375	0.0224	0.0228	1.79
0.500	0.0227	0.0226	0.44
0.625	0.0239	0.0236	1.26
0.750	0.0246	0.0244	0.81

(b)

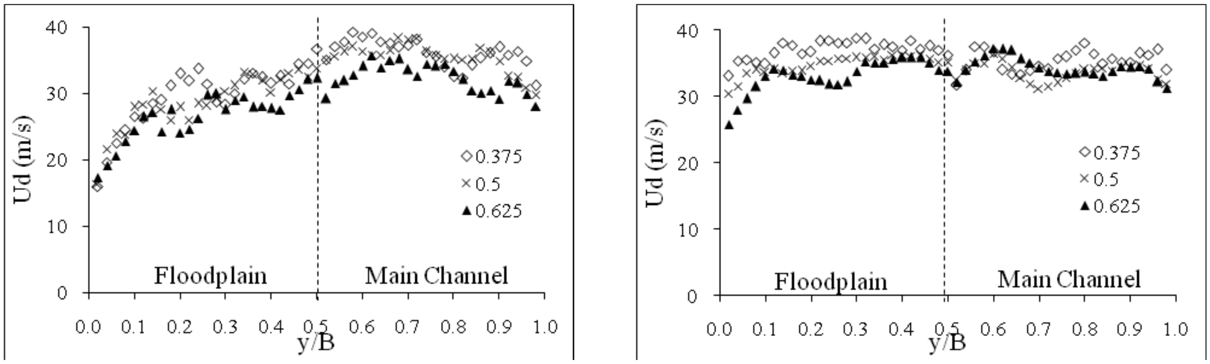
x/L	Experimental n	Cox Method n_c	% Difference
0.250	0.0205	0.0216	5.37
0.375	0.0222	0.0225	1.35
0.500	0.0245	0.0248	1.22
0.625	0.0251	0.0251	0.00
0.750	0.0250	0.0249	0.40

(c)

Depth-Averaged Velocity Distribution

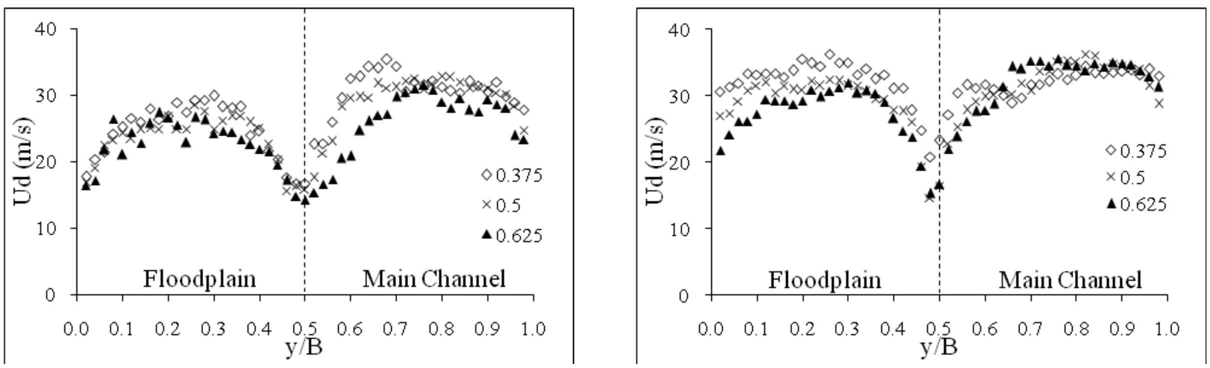
The velocity is measured in several cross sections using Acoustic Doppler Velocity Meter (ADV). The data of velocity is taken at the relative depth (DR) of 0.30 and 0.50 respectively. For each relative depth, velocity is taken at different locations (x/L) which is 0.375, 0.500 and 0.625. The depth-averaged velocity (Ud) is obtained from the value of mean velocity component for each point in the straight compound channel. Figure 5 to 7 illustrates the depth-averaged velocity distribution at DR=0.30 and DR=0.50 for the each cases. From the observation, the absent of vegetation on the floodplain make the depth-averaged velocity at main channel for shallow overbank flow higher than on the floodplain. On contrary, in deep overbank flow the velocity is distribution almost evenly at centre region of the channel.

Based on Figure 6 and 7, the pattern of the velocity distribution for tandem and staggered vegetated of the flow is quite similar. The both figures below clearly show the flow velocity occurs in the centre of the main channel region is higher than floodplain region. This is because the interruption of flows by arrangement of vegetation which is generated by rod at the floodplain region. On the other hand, the depth-averaged velocity at the edge of the floodplain decreases near to zero due to the friction occurs between the water flow and the channel walls. Besides that, this condition occurs due to different depth between floodplain and main channel. Furthermore, in the vegetation cases, it has been shown that the velocity is reduced drastically when the flow move from the main channel to the floodplain. This is because of the momentum transfer from the main channel to the floodplain.



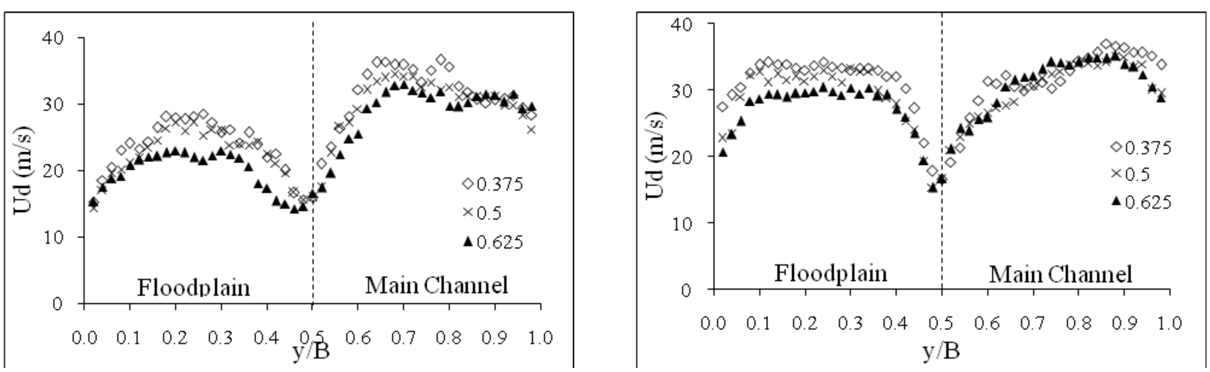
(a) (b)

Figure 5: Depth-average velocity for non-vegetated case in compound straight channel for (a) DR=0.30 and (b) DR =0.50



(a) (b)

Figure 6: Depth average velocity for tandem case in compound straight channel for (a) DR=0.30 and (b) DR =0.50



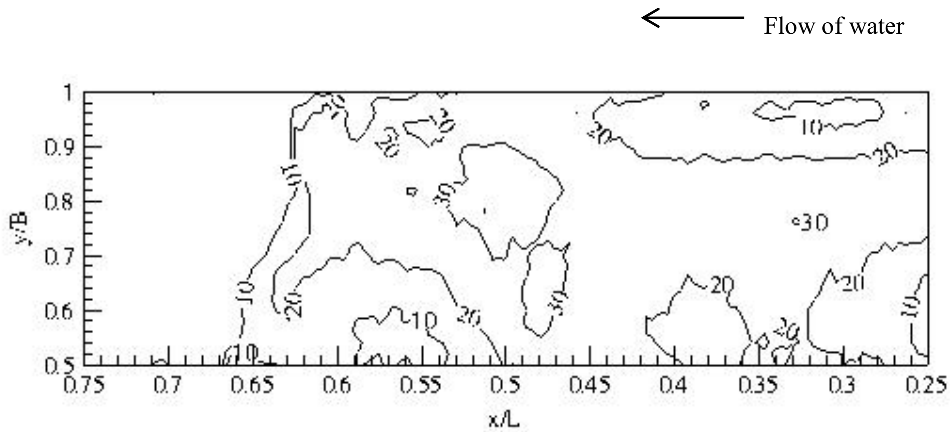
(a) (b)

Figure 7: Depth average velocity for staggered case in compound straight channel for (a) DR=0.30 and (b) DR =0.50

Bed Formation

In this section, results of bed formation for different cases and relative depth (DR) are discussed. The visualization of bed contour in the main channel is plotted using the Techplot 360 software. The value were used to plot the contour are height of channel as value at Z-axis (H), wide channel as Y-axis (y/B) and the lateral channel in X-axis (x/L). The value of contour lower than 0 mm indicates erosion while the values of contour higher than 0 mm indicate deposition. Figure 8 a plan view of bed formation for non-vegetated for different relative depth. Meanwhile, Figure 9 and 10 shows a plan view of bed formation for emergent vegetation for different relative depth.

The bed formation processes involve sedimentation and erosion phenomena due to water flow in main channel. In this study, it can be found that the differences in bed profiles for each interval of x-direction due to difference of relative depth (DR). Figure 9 and 10 shows a plan view of bed formation for vegetation floodplain with tandem and staggered array on main channel with relative depth 0.3 and 0.5 respectively. The pattern of bed form for staggered and tandem array vegetation is quite similar in terms of erosion and sedimentation. Based on Figure 9(b) the maximum level of erosion is -40mm and Figure 10(b) is -60mm. The bed forms show that the erosion occurs at upstream and slightly occurs at downstream part. Meanwhile, the sediments more deposited in mobile bed towards downstream area. Furthermore, these finding of this research are consistent with Jumain who found the sedimentation and erosion of sand are mostly occurred in the main channel cause of the higher velocity of water flow in the main channel [2].



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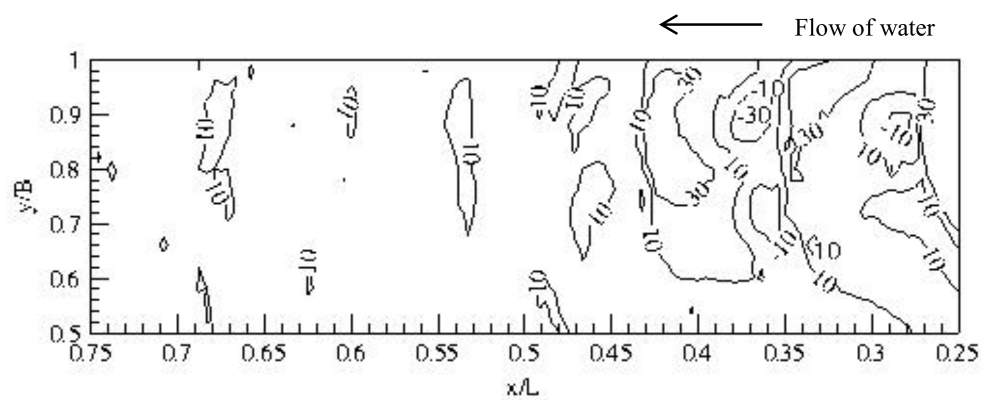
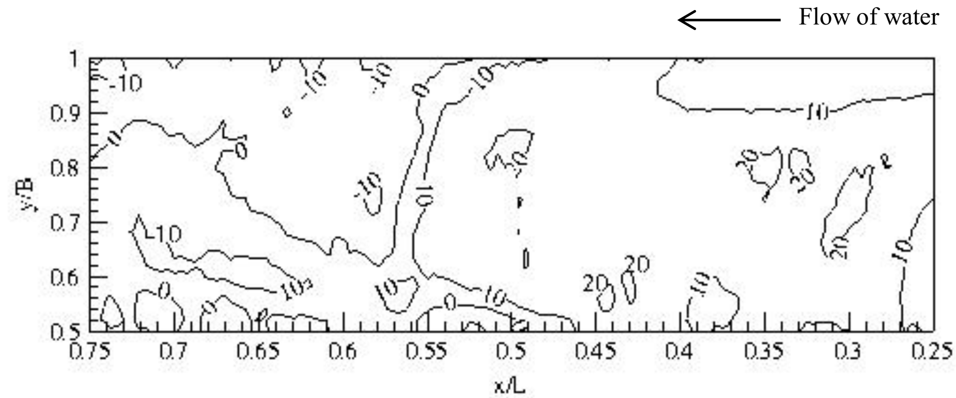


(b)

Figure 8: Plan view of bed formation for non-vegetated at relative depth (a) DR=0.30 and (b) DR=0.50



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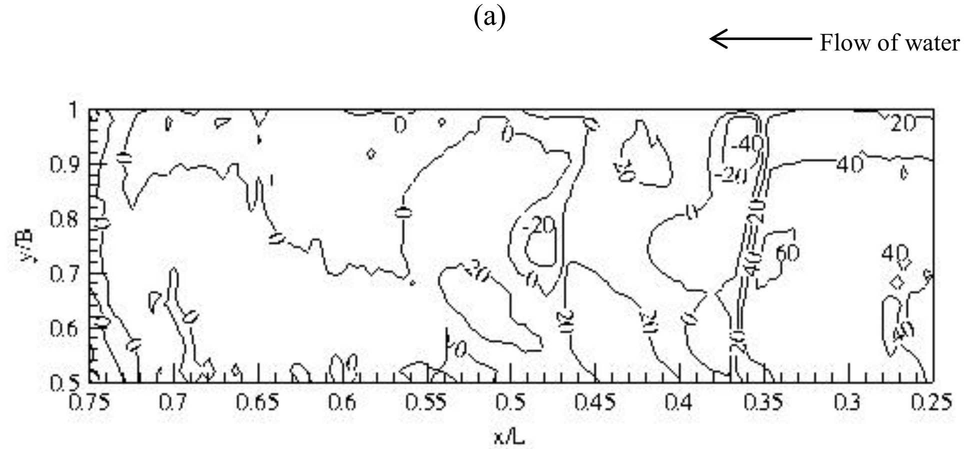
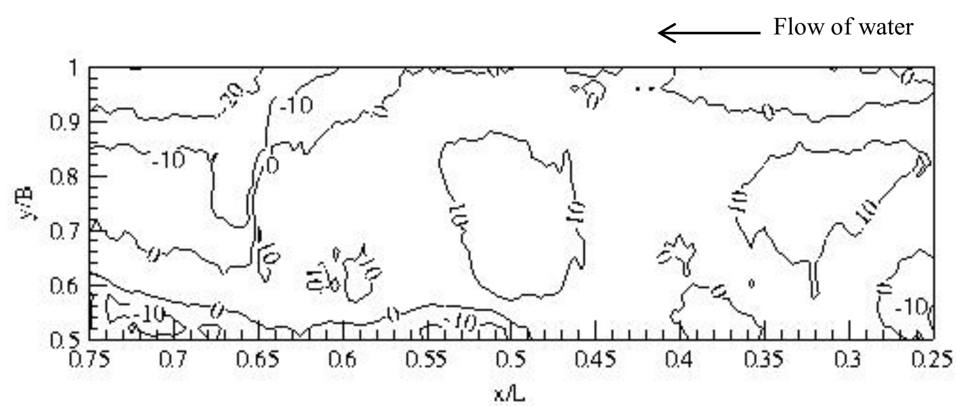


(b)

Figure 9: Plan view of bed formation for tandem vegetated at relative depth (a) DR=0.30 and (b) DR=0.50



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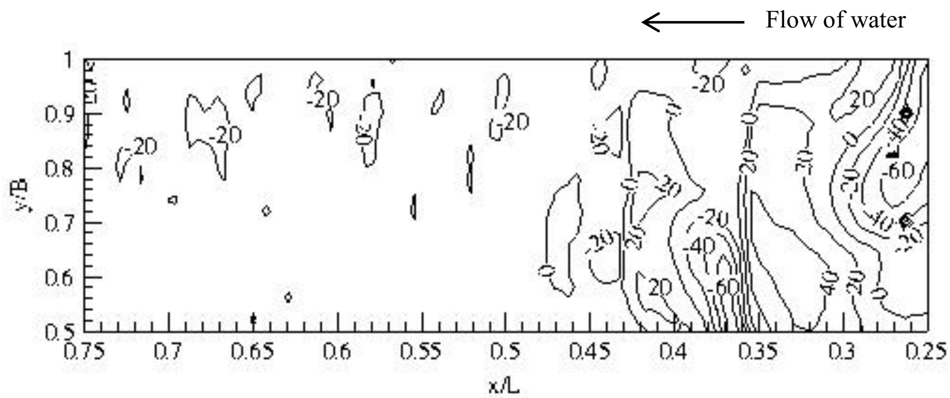


(b)

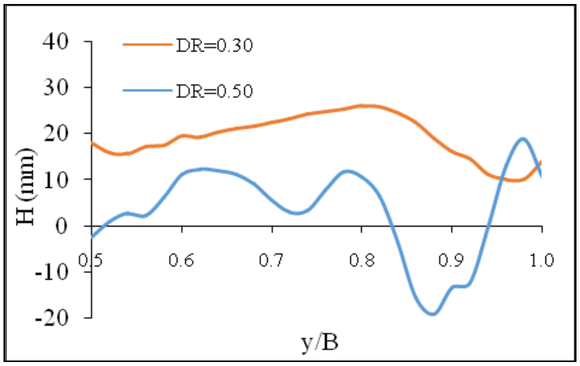
Figure 10: Plan view of bed formation for staggered vegetated at relative depth (a) DR=0.30 and (b) DR=0.50

Cross-section of bed formation

The cross-section profile was considered to recognize the flow pattern and bed elevation for identify the sediment deposition and erosion in the main channel. In the main channel, the water flows towards downstream area make sediment becomes more deposited on the bed due to energy create by upstream flow. These conditions increase the flow resistance and create slow velocity near the mobile bed area. It can be seen on figure below, the various pattern of cross section of bed formation illustrated at different chainage. Figure 11 to 13 shows the cross section of bed formation at different chainage (a) x/L=0.375, (b) x/L=0.500, (c) x/L= 0.625 for difference cases of DR=0.30 and DR=0.50.

During the water flow, the changing of sand surface level in the main channel is due to sedimentation and erosion. By observing the pattern of cross section at Figure 11 (b), sedimentation and erosion phenomena occurred at the same place. However, sedimentation has the maximum level at relative depth 0.30 which is 33.55mm where at relative depth 0.50 is 8.38 mm. The same condition occurs in emergent vegetated at (x/L=0.500) which is sedimentation of relative depth 0.30 is higher than relative depth 0.50. The bed forms show that sedimentation at relative depth 0.30 mostly occurs at the most part in the main channel especially at (x/L=0.500). Based on the study, the decreasing of relative depth influenced in increasing of sediment transport in the main channel. Therefore, the lower the level of relative depth in the main channel leads to increasing the velocity of flow and flow resistance towards the downstream area.

In this study, the presence of vegetation also influenced of changing for sand surface level. Vegetation will increases the flow resistance on the floodplain and leads to increases velocity in the main channel. Figure10 and 11 shows the cross section of bed formation at different chainage (a) x/L= 0.375, (b) x/L=0.500, (c) x/L=0.625 for vegetation floodplain with tandem and staggered array on main channel with relative depth 0.3 and 0.5 respectively. The pattern of bed form for staggered and tandem array vegetation is quite similar in terms of erosion and sedimentation. However, cross section at (x/L=0.375) for relative depth 0.5, for staggered vegetated arrangement, the maximum erosion is -59.23mm meanwhile for tandem vegetated arrangement, the maximum erosion is -19.07mm. The difference level of sand erosion proves that the arrangements of vegetation also affect the bed form in the channel.



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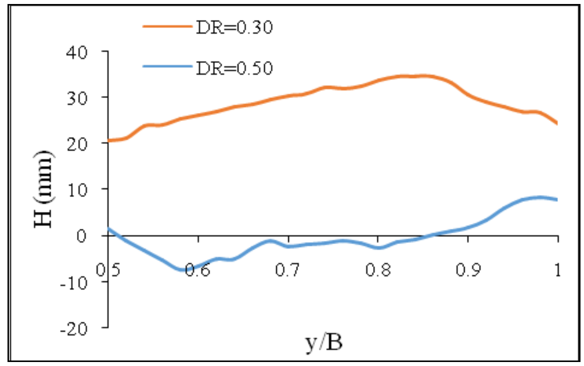

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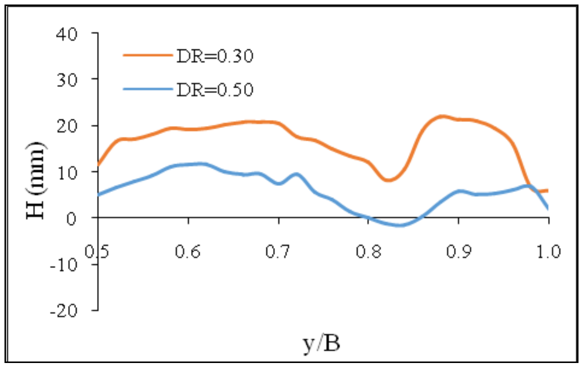
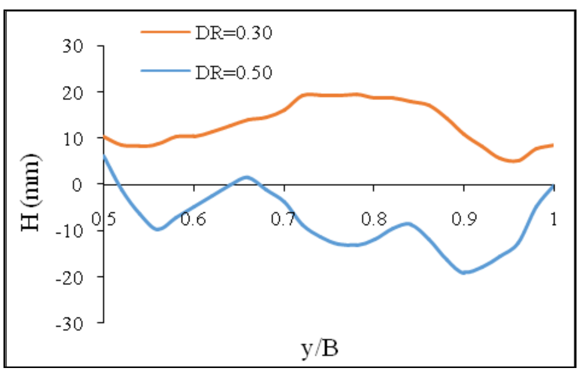


(c)

Figure 11: Cross section of bed formation at different chainage (a) x/L=0.375, (b) x/L=0.500, (c) x/L=0.625 for non-vegetated DR=0.30 and DR=0.50



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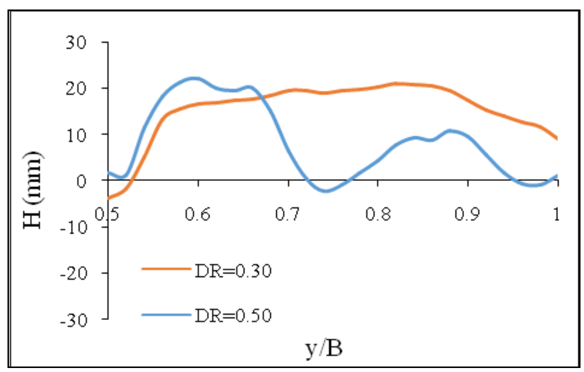
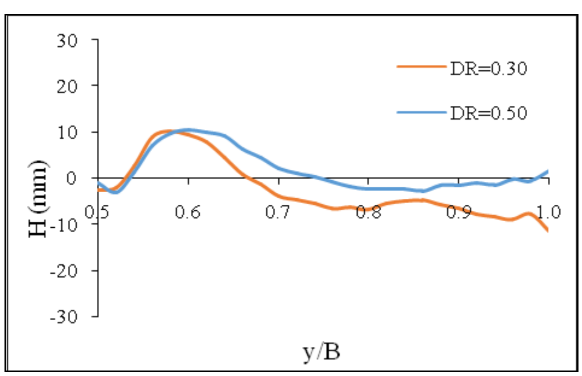
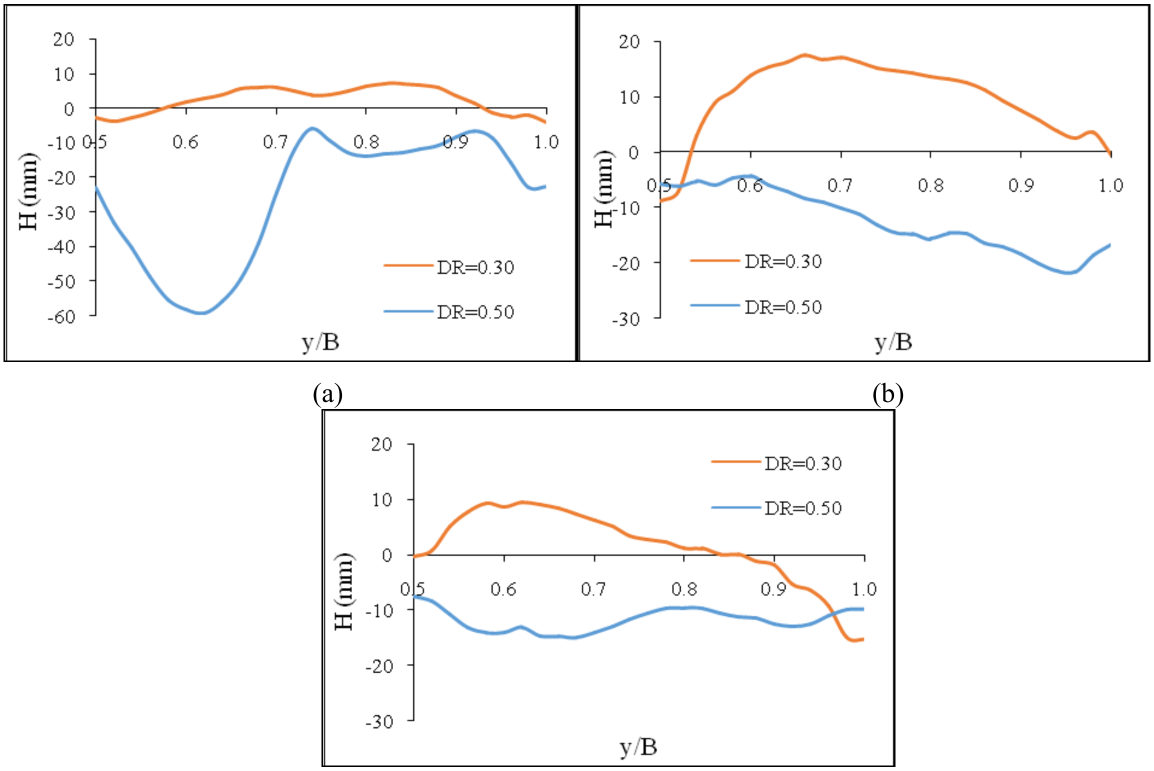


(b)



(c)

Figure 12: Cross section of bed formation at different chainage (a) x/L= 0.375, (b) x/L=0.500, (c) x/L=0.625 for vegetation floodplain with tandem array DR=0.30 and DR=0.50



(a) (b)

(c)

Figure 13: Cross section of bed formation at different chainage (a) x/L=0.375, (b) x/L=0.500, (c) x/L=0.625 for vegetation floodplain with staggered array DR=0.30 and DR=0.50

Conclusion

From the experimental had been done, the conclusion are based on the:

i. For stage-discharge relationship the flow depths are steadily increases with an increase in discharge for each case. The highest value of flow depth is occurring in staggered vegetation case followed by tandem vegetation case and lastly non-vegetation case. This is due to the existed of vegetation at the floodplain generally increase the flow depth in the main channel.

ii. The values of Manning's n are increases along the channel in downstream direction because the flows of water in the main channel toward downstream area make the sediment become deposited on the bed since the energy creates by upstream flow.

iii. For non-vegetated case, in deep overbank flow the velocity is distributed almost evenly at centre region of the main channel to the floodplain area. For vegetated case, the depth-average velocity distribution higher in main channel region than floodplain region. In the middle of intersection, the velocities also decrease near to zero towards the channel wall and interface region due to friction between the water flow and the surface of the channel.

iv. The bed formation processes involve sedimentation and erosion phenomena due to water flow in main channel. The bed form profiles for are quite different based on relative depths and flow conditions. In this study, the bed form profiles are repeating ripples and dunes.

References

[1] D/iya, S. G., Gasim, M. B., Toriman, M. E., and Abdullahi, M. G.,. "International Journal of Interdisiplinary Reserch and Inovations." *FLOODS IN MALAYSIA Historical Reviews, Causes, Effects and Mitigations Approch* 2, no. 4 (October-December 2014): 59-65.

[2] Jumain, M., Ibrahim, Z., Ismail, Z., Ibrahim, N. H., Makhtar, M. R., and Nordin, M. R.,. "Influence of Two-line Emergent Floodplain Vegetation on A Straight Compound Channel." *International Journal of Integrated Engineering* 5 (2013): 58-63.

[3] Bousmar, D., Jacqmin, T., Wyseur, S., and Van Emelen, S.,. "Flow in skewed compound channels with rough floodplains." 2012.

[4] Fernandes, J., J.B.Leal, and Cardoso, A.,. "Flow structure in a compound channel with smooth and rough floodplain." *European Water* 38 (2012): 3-12.

[5] Khairi, S. S.,. *Influence of Two-Line Emergent Floodplain Vegetation on Mobile Bed Straight Compound Channel Hydraulics.* Faculty of Civil Engineering, Universiti Teknologi Malaysia, 2015.

[6] Imran, N. S., *Influence of Two-lined Emegent Floodplain Vegetation on Mobile Bed Straight Compound Channel Hydraulics.* Faculty of Civil Engineering, Universiti Teknologi Malaysia, 2015.

[7] Masri, K. A., "Flow Characteristics of Straight Compound Channels With Staggered Main Channel Vegetation." Faculty of Civil Engineering, Universiti Teknologi Malaysia , 2011.

[8] Abidin, R. E., *Determintion of flow characteristics in a straight rectangular compound channel.* Universiti Teknologi Malaysia , 2010.

[9] Ibrahim, N. H., *Flow Characteristics in a Straight Compund Channel with Two-Line Emergent Floodplain Vegetation.* Universiti Teknologi Malaysia, 2012.

[10] Yonesi, H. A., Omid, M. H., and Ayyoubzadeh, S. A., "Journal of Civil Engineering and Urbanism." *The Hydraulics of Flow in Non-Prismatic Compound Channels* 3, no. 6 (2013): 342-356.

[11] Hickin, E. J., *River geomorphology.* Edited by Edward J Hickin. Wiley, 1995.

[12] Hossain, S. M., Adham, A., and Uddin, M., "Stream Barb Influenced on Straight Channel Bed Configuration: A Numerical Simulation." *J. Environ. Sci & Natural Resources*, no. 6(2) (2013): 139-147.

[13] Anuar, M. Z., *Flow Characteristics in Straight Compound Channel with Mobile Bed.* Universiti Teknologi Malaysia, 2014.